NHDOT SPR2 PROGRAM
RESEARCH PROGRESS REPORT

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a progress report at least every three months during the project duration. Reports are due the 5th of the month following the end of the quarter. Please provide a project update even if no work was done during this reporting period.

Project # 26962M	**Report Period** Year: 2017 ☐Q1 (Jan-Mar) ☐Q2 (Apr-Jun) XQ3 (Jul-Sep) ☐Q4 (Oct-Dec)	
Project Title: Evaluation of Gusset-less Truss Connection to Aid Bridge Inspection and Condition Assessment		
Project Investigator: Erin S. Bell Co-Project Investigator: Ricardo Medina **Phone: (603)862-3850** **E-mail: erin.bell@unh.edu**		
Research Start Date: December 15, 2016	**Research End Date:** December 31, 2018	**Project schedule status:** ☐ On schedule ☐ Ahead of schedule X Behind schedule

Brief Project Description:

The Memorial Bridge connecting Portsmouth, NH and Kittery, ME was re-opened to traffic in 2013. One of the major innovations of the reconstructed bridge is the first ever gusset-less truss connection in a vehicular bridge in the United States. Traditional gusset plates are the most vulnerable element in a truss-bridge structure and a source of significant cost, effort, and concern for bridge managers and owners. The goal of the proposed research is to integrate field-collected performance data, laboratory experimental testing, and physics-based structural modeling to develop a protocol to assess the condition and predict the remaining life of the gusset-less truss connections used at the Memorial Bridge. It is anticipated that the aforementioned approach will be modified to develop a framework to extend this protocol for application to future innovative structural elements.

The objectives of this project are to:

- Original Objective: Create two specimen pairs (A and B) of a scale model of a gusset-less connection from the Memorial Bridge. Specimen pair A (top chord connection) will be tested to failure in a quasi-static testing protocol and Specimen pair B (bottom chord connection) will be tested for fatigue performance. Modified Objective: Create two specimens that are a scaled model of the gusset-less connection from the Memorial Bridge focused on the radiused weld section of the connection.
- Conduct quasi-static set of tests on each member of Specimen A to determine stress distribution in the connection.
- Evaluate these results in conjunction with field collected data and analytical models that are the work product of a complimentary FHWA-AID DEMO project to: (i) further understand and quantify the structural performance of the gusset-less connection, and (ii) validate analytical models.
- Conduct fatigue testing on Specimen pair B and collect performance data to determine the stress pattern and predict fatigue failure mode.
- Compare the findings of this project with the FHWA guideline for connection assessment to facilitate the development of an evaluation protocol for inspection and structural condition assessment.

Progress this Quarter (include meetings, installations, equipment purchases, significant progress, etc.):

Complete Literature Review and Finalize Testing Plan

This literature review and testing plan was started as part of PI Bell's graduate course in advanced steel design and has

continued in the spring as part of co-PI Medina's experimental structural dynamics class. This literature review has included an evaluation of the summary calculations for the gusset-less connection provided by HNTB, which were made available to the research team after the project proposal was submitted. A graduate student, Fernanda Fischer, completed a majority of this task by June 2017. Additional topics were added to the literature survey scope at the May 19th TAG meeting, including the impact of weld defects on the fatigue life of welded connections.

Design and Construction of Scale Models

In the previous quarter, weld specimens with and without defects were fabricated to evaluate the fatigue performance of intact and defective ½" welds. As part of this effort, a mock test was performed. Due to limitations of the testing machine, significant slippage was present during the cyclic test and an alternative testing approach was designed. The Civil and Environmental Engineering Department procured grips to be attached to the Instron Universal Testing Machine at the UNH Structural Engineering Laboratory (Figure 1). The advantage of using the aforementioned grips is twofold: (i) the grips prevents any slippage in the response once the specimens are exposed to cyclic loading, and (ii) time and resources are saved given that specimens do not need to be machined to a circular cross-section and specimens with square cross-sections can be tested without modifications. The grips arrived toward the end of this quarter and their installation process is in its final stage. Figure 2 shows one of the specimens to be tested. The only machining necessary involved reducing the cross-section in the middle of the specimen (where the weld is located) in order to induce fatigue failure at this location.

Figure 1: Grips installed at the Instron Machine

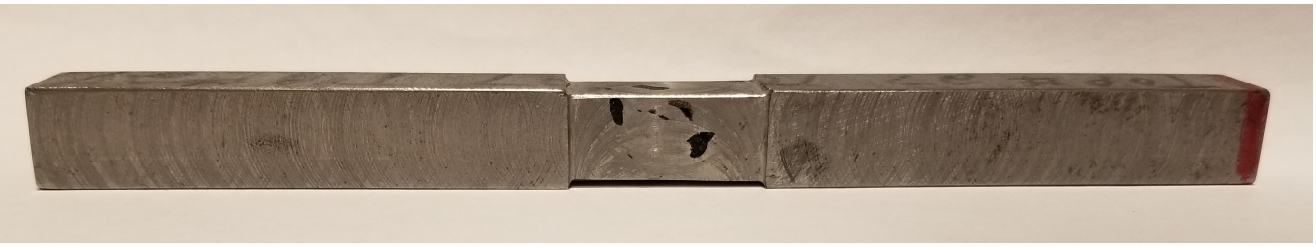

Figure 2: Example weld specimen

Analytical Models of Small-scale Physical Specimens

During this quarter, numerical models that represent a modified version of the gusset-less connection were generated using the software Abaqus. The final model, which had a geometric scale of 1:2.571, was completed during this quarter. This model was used not only to study the local response of the connection but also to inform the design and fabrication of the specimens for fatigue testing. Figure 3 shows the numerical model of the connection including a representation of the loading actuator and the its attachment to one end of the specimen. In this model, the welds around the plate and around the bend radius were explicitly modeled. The predicted stress contours from the model are shown in Figure 3. These stress contours and their magnitudes are consistent with those obtained by the designer of the bridge when evaluating the demands on the fillet welds along the bend radius of a typical lower-chord connection that was exposed to load combinations associated with the controlling fatigue limit state.

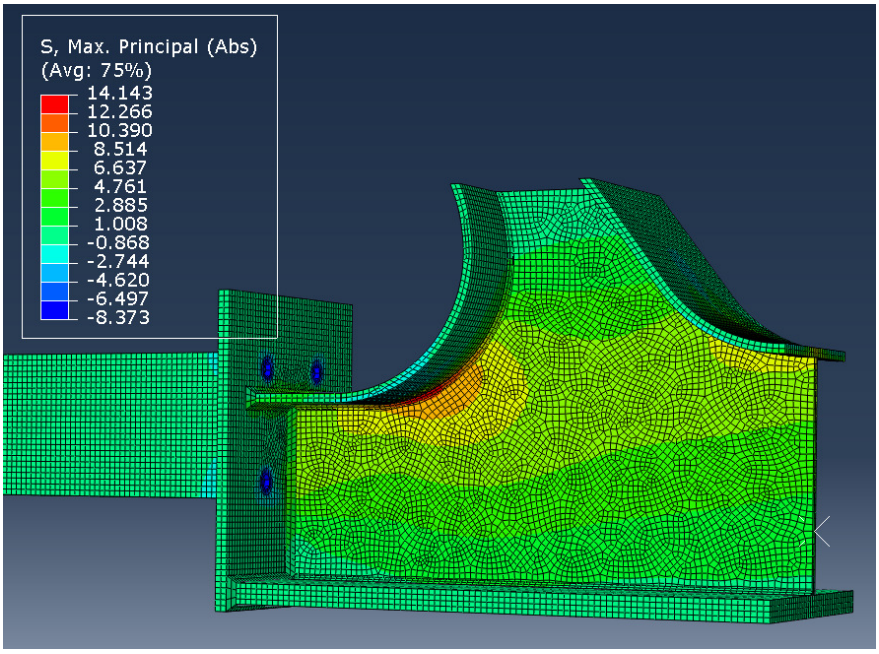

Figure 3: Maximum Principal Absolute stresses of the specimen

Quasi-Static Testing

As decided in the May 19th TAG meeting, a load test will take the place of the quasi-static testing. The load test of the Memorial Bridge is planned for October 2017. Two testing windows, October 16-18 and October 23- are currently being

scheduled for the load test with bridge operations.

Validation of Structural Connection Analytical Model

The numerical model developed during this quarter has not been validated based on load test data. However, as reported in the section titled *Analytical Models of Small-scale Physical Specimens*, this model provided consistent results with those obtained using the model developed and utilized for the design of the bridge. The bulk of this task is expected to be completed in the next quarter once results from the load test become available.

Fatigue Testing

The main test limitation is the availability of a single fatigue-rated actuator with a capacity of 110 kips at the UNH Structural Engineering Laboratory. Given this limitation, a test setup was designed based on numerical models in Abaqus (Figure 3) that provide a distribution of stresses on the fillet weld along the bend radius consistent with those estimated during the design of the bridge. The scale of the specimen and the exact location of the actuator were decided based on the actuator-load capacity in order to achieve the desirable stresses in the area under study and to have the appropriate dimensions and capacity to be tested at the UNH Structural Engineering Laboratory. Two specimens will be fabricated and exposed first to cyclic stress ranges consistent with the design stress ranges. Cyclic stress ranges will then increase up to the design allowable stress range, and if the specimen does not fail, stress ranges will be further increased until failure is imminent. The specimen dimensions are shown in Figure 4.

The specimens are scheduled to be fabricated within the first few weeks of the next quarter as per our latest communication with CANAM Bridge (dated Monday, October 2nd).

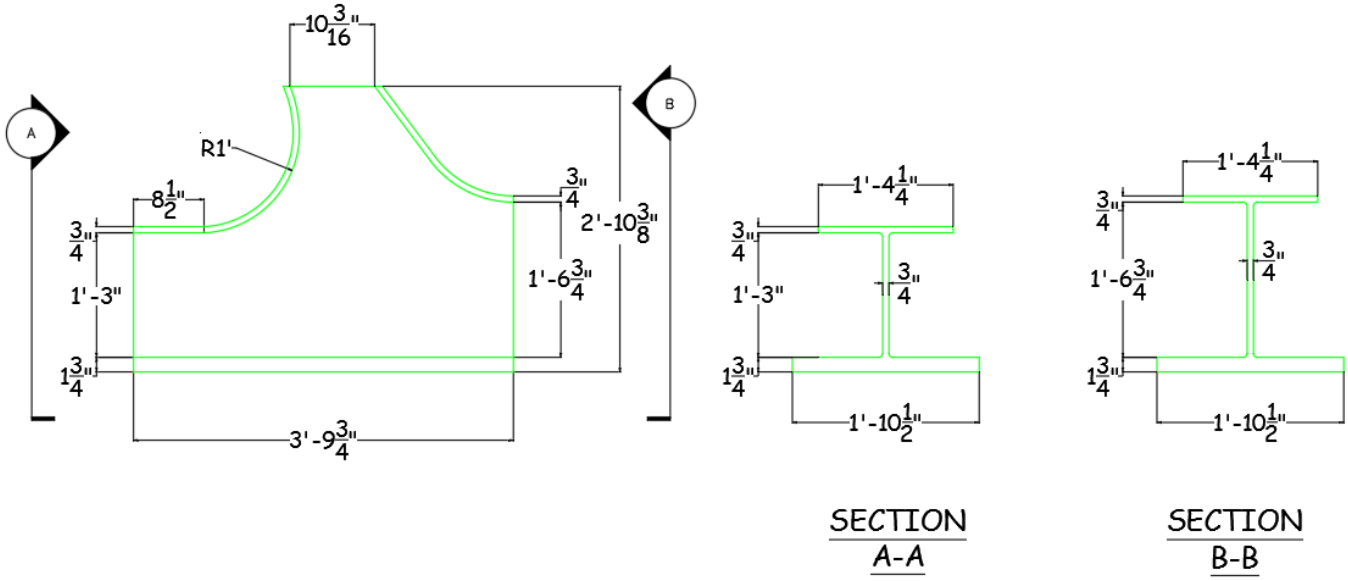

Figure 4: Dimensions of specimen

In addition, during this quarter, a reaction block was designed to support the base of the actuator (see Figure 5). This reaction block will be anchored to the strong floor of the UNH Structural Engineering Laboratory. We are currently in the process of obtaining quotes for the fabrication of the reaction block. The support at the other end of the connection is also currently under design (i.e., boundary support in Figure 5).

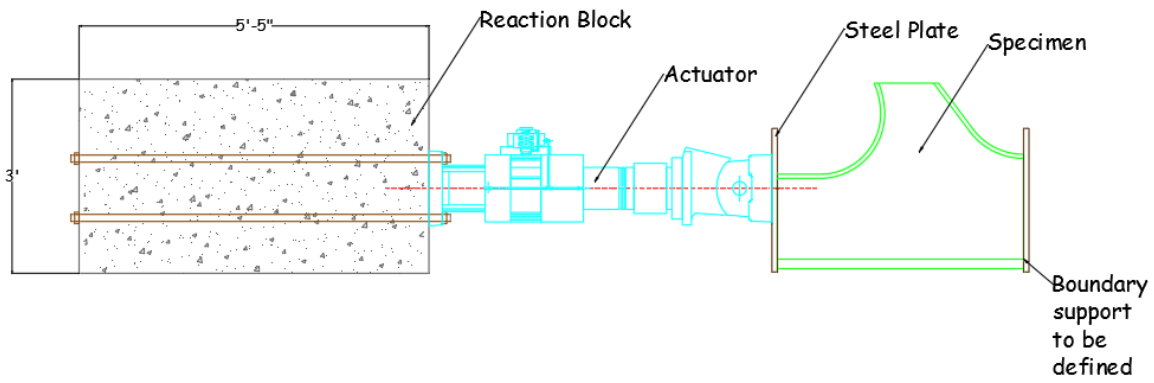

Figure 5: Test set-up showing reaction block

Data Analysis and Interpretation of Laboratory Testing
There was no progress on this task during this reporting period.

Evaluation Protocol for Inspection and Condition Assessment
There was no progress on this task during this reporting period.

Final Report and Presentation
There was no progress on this task during this reporting period.

Items needed from NHDOT (i.e., Concurrence, Sub-contract, Assignments, Samples, Testing, etc):

There are no items needed from the NHDOT at this time. The research team is planning for the load test and will need the support of the NHDOT for this load test.

The research team would like to request a TAG meeting to review the laboratory final testing plan in late October 2017 after the fatigue testing set up is completed..

Anticipated research next 3 months:

Complete literature review.

Complete the fatigue testing of weld samples – intact and defective and identify the appropriate defect inform the design of the bottom chord, gusset-less connection specimen to be used for subsequent fatigue testing.

Use field data for the strain gauges installed at the Memorial Bridge for final calibration of numerical models of the bridge.

Finalize the fatigue test setup at the UNH Structural Engineering Laboratory and conduct a fatigue test with a mock specimen. This completion of this task depends when the CanAm, the fabricator for the gusset-less connection, completes the fabrication of the test specimens. The research team talked with Tony Matuis of CanAm on Monday, October 2, 2017. During this conversation, Mr. Matius informed the team that he was sending the drawing to a project manager and would be in touch with a delivery date in the coming weeks.

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Circumstances affecting project: Describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope, and budget, along with recommended solutions to those problems.

As described in the previous quarterly reports, delays associated with specimen fabrication, the need to modify the Instron Universal Testing Machine at UNH, and technical issues relating to the data acquisition system at the Memorial Bridge have negatively affected the schedule of this project.

Tasks (from Work Plan)	Planned % Complete	Actual % Complete
Evaluation of Gusset-less Truss Connection to Aid Bridge Inspection and Condition Assessment		
Literature Review and Finalize Testing Plan	**100**	**100**
Design and Construction of Small-scale Physical Models	**90**	**75**
Quasi-Static Testing to Failure – Replaced by Load Test of the in-service connection at the Memorial Bridge	**100**	**50**
Validation of Structural Connection Analytical Model	**20**	**20**
Fatigue Testing	**50**	**10**
Data Analysis and Interpretation of Laboratory Testing	**0**	**0**
Evaluation Protocol for Inspection and Condition Assessment	**0**	**0**
Final Report and Poster	**0**	**0**